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Proposal of New Terminology for the Morphology of Nauplius Y (Crustacea: Maxillopoda: Facetotecta), with Provisional Designation of Four Naupliar Types from Japan

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ABSTRACT—New terminology for the morphology of first stage nauplius y larvae, mainly for the plates on their cephalic shield, is proposed. The proposed terminology aids in the identification of plates which vary in place and/or shape among naupliar types, and simplifies the description of nauplius y larvae. Four nauplius y larvae from Japan which are cited to explain the terminology are provisionally designated as separate types, symbolized as VIII–a, IX, X, and XI, the last being for the nauplius which was formerly described as a larva of *Hansenocaris pacifica* Itô.

INTRODUCTION

The nauplius y type IV larvae originally described by Hansen [1] and later reviewed by Schram [2] are characterized by the sculpture made of many clear "plates" on the cephalic shield. Many undescribed nauplii which are more or less similar to type IV in cephalic-shield sculpture are present in Tanabe Bay on the Pacific coast of Japan, where three types of nauplius y larvae have already been reported [3]. During the past three years I have raised many different nauplii into "cypris y" stages in the laboratory (for an abstract of the first successful case see [4]). The results of these rearing experiments should be taxonomically useful because the current taxonomy within the Facetotecta is based only upon the cypris y stage and remains tentative [5]. However, the lack of adequate terminology to describe cephalic-shield plates of different shapes and different arrangements poses an unexpected problem. Steuer [6] tried to identify plates of his material with their counterparts in Hansen's type IV larva by labeling them alphanumerically, and Schram [2] named plates in an advanced manner (see Fig. 1A). Although Schram's terminology, which was based upon the smallest form of his type IV larvae, seemed to be usable for my material, its application to various nauplius y larvae in Japan has often been very difficult even for larvae at the same stage (first naupliar stage) as his smallest form. Therefore, I have had to modify Schram's terminology to make it more universal. This improved terminology for first stage larvae, which is described in the present paper, will facilitate our forthcoming descriptive works on nauplius y larvae.

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Provisional designation of naupliar types

Three of the four nauplii cited in the present paper (Fig. 2) are selected from undescribed forms found in Tanabe Bay on the Pacific coast of Japan. They are provisionally named as types VIII–a, IX, and X, though they will be fully described in forthcoming papers. The other one cited in this paper is called type XI; this nauplius was formerly described by Itô [3] as a nauplius of *Hansenocaris pacifica* Itô, 1985. Closer examination has revealed that this form is not the larva of *H. pacifica* but belongs to a separate species, the cypris y stage and the naupliar development of which are to be described elsewhere.

Comments on larval stages and general morphology

To judge from my successful rearing experi-

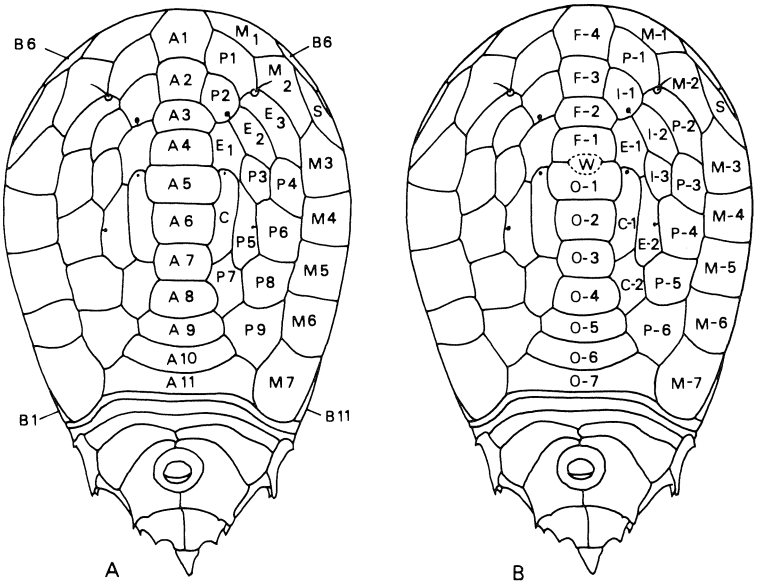

FIG. 1. Diagrams showing relationship between Schram's terminology (A) and new terminology (B) for cephalic-shield plates. The diagram A was redrawn from Schram [2] with permission. Abbreviations— A: axial; B: brim; C: crescentic; E: elongate; F: frontal; I: intercalary; M: marginal; O: occipital; P: polygonal; S: superlateral; W: window.

ments, the number of naupliar stages of facetotectans is typically five. The four naupliar types from Japan cited in the present paper represent the first naupliar stages of four separate species. It is apparent from certain characteristics in the structure of the cephalic shield that the original type IV larva described by Hansen [1] is also the first naupliar stage of a separate species. Characteristics available for identification of each stage will be dealt with elsewhere.

In the present paper the term "cephalic shield" is used to denote a particular dorso-anterior part of integument of the nauplius y larvae. The remainder of the integument is not yet named; I would like to call it "faciotruncal" integument. The border between these two parts is occasionally unclear, especially in a larva at an intermolt phase, so one might doubt the necessity for discriminating the cephalic shield from the faciotruncal integument. However, they are actually separate units of the naupliar integument. After a molting, a nauplius y larva often leaves two partial exuviae; the dome-shaped one with no appendages is the cephalic shield and the other one with appendages is the faciotruncal integument. When a nauplius starts to molt, the cephalic shield splits from the faciotruncal integument except along its rear edge and is pushed up by the emerging body which exits through this anteriorly facing gap. The connection between these two parts of the cast integument is weak and they easily detach from each other; the true contour of the cephalic shield can be clearly determined by examining such a cast one.

TERMINOLOGY

As can be seen in Figure 2 (especially A and E), the cephalic-shield plates principally form almost concentric circles interrupted by a midlongitudinal belt of plates. This latter belt is separated into two parts by a single special plate called "window" (abbreviated as "W"; in the following description, parenthesized symbols represent abbreviated forms of plate names); the plates which form the anterior belt are called "frontal" plates and numbered toward the front (F–1 to F–4), and the plates which form the posterior belt are called "occipital" plates and are numbered toward the

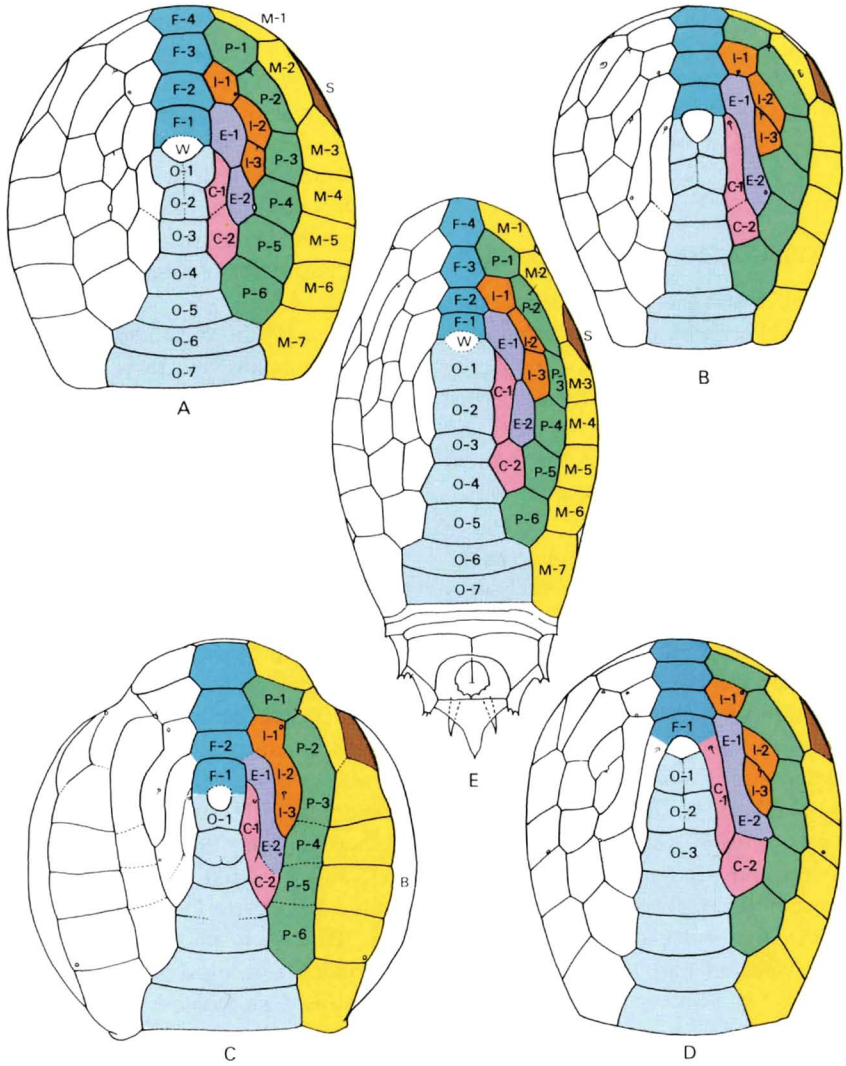

FIG. 2. Diagrams showing cephalic-shield plates of four naupliar types from Japan and Hansen's type IV larva. A: Type X; B: Type IX; C: Type VIII–a; D: Type XI; E: Hansen's type IV (window is not illustrated in the original figure by Hansen). For abbreviations see Fig. 1.

rear (O–1 to O–7). These frontal, window, and occipital plates may all be called "axial" plates (the reason is mentioned later).

The following explanation refers to the plates (or plate groups) of only one half of the cephalic shield, because the plate arrangement is symmetrical about the axials. The plates of all non-axial plate groups are numbered toward the rear.

Two plates which are placed alongside some of the anterior occipitals are called "crescentic" plates (C–1 and C–2). Two plates which are placed antero-lateral to the crescentics are called "elongate" plates (E–1 and E–2). Three plates which are placed antero-lateral to the elongates are called "intercalary" plates (I–1 to I–3). Six plates which border the outer sides of the intercalaries, E–2, C–2, and a few posterior occipitals are called "polygonal" plates (P–1 to P–6). Seven plates which border the outer sides of the polygonals are called "marginal" plates (M–1 to M–7).

There is a triangular plate which wedges itself between M–2 and M–3; it is called the "superlateral" plate (S). The externalmost part of the cephalic shield except for its rear edge (the rear edge of O–7) is called "brim" (B) as a whole (Fig. 2C).

FURTHER EXPLANATION AND DISCUSSION

Schram's "axial" plates (A1 to A11; in Schram's terminology, an abbreviated plate name is represented by a combination of a capital letter and a number with no hyphen between them) accord with the longitudinal belt of frontal, window, and occipital plates of my terminology (cf. Fig. 1A and B). The reason for dividing this simple belt of plates is given below.

With a light microscope we usually observe the cephalic shield which is mounted horizontally on a slide glass in dorsal view, not in frontal (anterior) view. To observe a cast cephalic shield in frontal view is actually impossible. This practical condition causes a difficulty in the observation of anterior plates. In certain nauplii the frontal region is rounded and in normal preparations is situated almost parallel to the line of sight. In such specimens, anterior axial plates appear to be closely appressed and accurate observations of their borders are difficult. This problem is more severe at later developmental stages because their axial plates are changed into numerous smaller plates by division. If Schram's terminology, in which the anteriormost plate is labeled the first axial (A1), were applied to nauplii whose first axial could not be surely ascertained, no axial plate could be confidently labeled, even an easily observable one on the top of the cephalic shield. My system avoids this difficulty because it starts from an easily identifiable plate, namely the window, which is placed almost on the top of the cephalic shield. As already reported by Itô [3], in two types of nauplius y from Tanabe Bay the window is a special plate above the nauplius eye; it is characterized by its smoothness (though partially filled with a mesh-like texture in certain nauplii), whereas other plates are usually not smooth, but of mesh-like texture.

Although the window is usually detectable in the first stage nauplius y larvae as shown in Figure 2, it is possible that we meet unusual nauplii in which the window is not detected. For describing such unusual nauplii the term "axial" in the sense of Schram would be still available and I think it should be reserved. It is also useful as a general term for a context in which there is no necessity to distinguish frontal, window, or occipital plates; in fact, I have already used it in this sense in former paragraphs.

Hansen [1] did not indicate the window in his type IV nauplius, but there is little doubt that it had a window because other similar nauplii have the window (Schram's larva 2 from Akeröya [2]; the nauplius illustrated by Steuer [6] based upon the material from Adriatic Sea). In Figure 2E, I indicate a possible situation of its window with reference to Schram's larva 2 from Akeröya. Schram clearly illustrates the window in his type IV larvae (especially in his Fig. 3E), and also mentions that "a circular platelete is present inside the original axial plate No. 5." The circular platelet (misspelled as "platelete") in his sense accords with the window. However, the window is not always a platelet embraced by A5 (0–1 in my terminology). The window of the type X nauplius is placed medially just between F–1 and O–1 (Fig. 2A), and it would be difficult to say that the window belongs to O–1. In the type IX nauplius (Fig. 2B), O–1 is subdivided with a faint ridge and the window is wedged deeply between the halves. In contrast, the window of the type XI nauplius does not appear to wedge itself deeply into the O–1, which is also subdivided as in type IX. The window of the type VIII–a nauplius is encircled with a single large plate, which seems to be a fusion of F–1 and O–1. Such a fused plate encircling the window can be called a "circum-window" plate.

Of the "crescentic" plates, C–1 is the same as Schram's single "crescentic" plate. However, I call a plate posterior to it the second crescentic (C–2), while Schram calls it "P7", namely the seventh polygonal. The main reason for considering Schram's P7 a "crescentic" plate is that the P7 has a tendency to fuse with the crescentic (cf. Fig. 2A, B, C). Another reason can be understood best in connection with the other polygonals *sensu*

Schram, which are dealt with later.

The first elongate plate (E–1) accords with the homonymic plate (E1) in the sense of Schram, but E–2 is called P5 in Schram's terminology. As can be seen in types IX and XI nauplii (Fig. 2B, D), E1 and P5 *sensu* Schram are fused with each other; hence, I treat P5 as an "elongate" plate. Similarly, P2, E2 and P3 have a tendency to fuse (cf. Figs. 1 and 2) and are regarded as members of the same plate-group. As there is no available name for them in Schram's terminology, the new term "intercalary" is introduced.

Among the intercalary plates of the type XI nauplius, I–2 and I–3 seem to form a unit isolated from I–1 (Fig. 2D). Similar arrangements are also seen in the other nauplii shown in Figure 2; for example, in the type IX nauplius (Fig. 2B), I–2 and I–3 are broadly connected with each other, while the connection between I–1 and I–2 is very narrow. In the intercalary plates, type X and Hansen's type IV nauplii are similar to type IX. In the type VIII–a nauplius, the three intercalary plates are fused with each other, but I–1 is still discernible from the others because the fused plate has a neck which indicates the border between I–1 and I–2.

My concept of the polygonal plates differs greatly from Schram's. Schram's polygonal plates occur as two groups separated by a radial row of three "elongate" plates (Fig. 1A). In types VIII–a and XI nauplii, there is no such radial row of plates; hence, elongate plates in the sense of Schram would be meaningless for these nauplii. Schram numbered the plates within the posterior group of polygonals outwards as he supposed transversal rows. However, such numbering is impossible for types IX, VIII–a and XI nauplii. I find it much more useful to recognize a row of plates which originates from P1 (the same as P–1) and extends posteriorly; thus, Schram's P2, P3, P5, and P7 are abandoned and, instead, a continuous row of six polygonal plates (P–1 to P–6) is formed. In the type VIII–a, five polygonal plates (P–2 to P–6) are almost fused with each other, which demonstrates the usefulness of this grouping.

The marginal (M–1 to M–7) and superlateral plates are the same as the homonymic ones in Schram's terminology. The brim is also the same as the homonymic part in Schram's terminology, though I do not yet recognize any first stage nauplius which has plates within the brim (Fig. 2 and [3]). The brim is usually not seen in dorsal view, but in the type VIII–a larva it is clearly seen even in dorsal view, except for an anterior portion (Fig. 2C).

The type XI nauplius has a peculiar single plate which has two "arms" extending posteriorly alongside the window, O–1, O–2, and O–3 plates (Fig. 2D). There is no doubt that this plate is made by fusion of F–1 and a pair of C–1 plates. A similar plate with two "arms" is present also in the type VIII–a nauplius (Fig. 2C), but it is made of F–2 fused with the E–1 and E–2 plates on each side.

Among the four nauplii from Tanabe Bay shown in Figure 2, the one closest to Hansen's type IV nauplius in the sculpture of the cephalic shield is the type X nauplius, although the proportions of its cephalic shield are greatly different. In contrast to these two similar nauplii, whose cephalic-shield plates may be regarded as the model of the proposed terminology, the other nauplii show various degrees of modification, mainly due to fusion and slight translocation of plates as already mentioned. However, it is important to acknowledge that their modified plates can readily be identified using the proposed terminology. These nauplii may be assumed to be closely related compared with other nauplii whose cephalic-shield sculpture can not be described using this terminology, like the type I nauplii described by Hansen [1] and Schram [7] or the Pacific type I described by Itô [5]. I expect that such similarity and dissimilarity in the fundamental structure of the cephalic-shield sculpture will be reflected in the taxonomy within the Facetotecta in the future.

The proposed terminology, which has been elaborated here specifically for application to the first naupliar stage, is also available for later naupliar stages to a certain extent, although it must be supplemented by other terms. An adaptation of this terminology to later stages will be demonstrated in a forthcoming paper which is in preparation.

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